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A TECHNIQUE FOR OPTIMAL FITTING OF FLIGHT HELMETS

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SUMMARY PAGE

THE PROBLEM

The lack of a standardized procedure for fitting flight helmets often results in a poor compromise that sacrifices noise exclusion for comfort.

FINDINGS

A procedure that involves use of a noise source and an automatic recording audiometer has been developed as an aid in the fitting process. The noise source allows the aviator to detect acoustical leakage around his ears so that a better fit can be effected. Masked hearing threshold levels obtained with the helmet's earphones can be used to demonstrate improved performance. Such a procedure would appear to be feasible for implementation at the squadron or air-group level.

INTRODUCTION

Prior to the development of the Sonex Earcup System (sound attenuating earcups), Navy flight helmets were regarded by psychoacousticians as having inadequate noise exclusion properties. The earpads were little more than receptacles for holding the earphones near the ears, while providing some support of the helmet on the head. Consequently, in the past no serious effort was made to adjust helmets for anything other than a loose, comfortable fit. Higher noise levels, such as those experienced in A-7 and OV-10 series aircraft, accelerated the development of an improved earcup system. Large numbers of APH-type helmets have since been fitted with the Sonex Earcup System, and the newer APH-6C helmets are currently being supplied with the earcups.

At present the only acoustical test being used in the evaluation of helmets is the real-ear attenuation test (1). This laboratory test procedure requires sophisticated psychoacoustical instrumentation and an anechoic chamber. Although helmets selected for Navy use on the basis of the real-ear attenuation test may possess exceptionally good noise attenuation qualities, these qualities may not always be realized when the helmet is worn, particularly when the helmet does not fit.

Any procedure for fitting aviators' flight helmets should result in a good compromise between a snug fit for maximum noise exclusion and a comfortable fit that can be tolerated for flights of long duration. Except, perhaps, for certain squadrons in which extremely noisy aircraft are used, there is no standard procedure for fitting flight helmets. Helmet fitting, if performed at all, is typically done in an environment that is considerably less noisy than that inside the aircraft. Conversational speech and handclaps are sometimes used by the aviator as crude sound sources for judging that there is a noticeable reduction in sound.

The need for fitting helmets for maximal noise attenuation in a simulated or real noise environment has been cited in a recent report by Working Group 54 of the National Research Council Committee on Hearing, Bioacoustics and Biomechanics (2). It would appear feasible to provide a simulated noise environment and a means of objectively evaluating any improvement in noise exclusion obtained during the fitting of a helmet. The noise need not necessarily be a particular aircraft noise spectrum but should be a continuous broad-band type with sufficient amplitude to allow the aviator to detect "leaks" around his ears and to cause masking of signals received via the earphones. An objective measurement of the relative improvement in performance could be obtained through use of speech or tone signals. Speech would provide for an evaluation of communications efficiency, while tones would provide information as to the degree to which discrete frequencies might be masked.

The purpose of this study was to develop and evaluate an efficient practical technique for optimal fitting of flight helmets. The technique sought was one that would not require any new equipment and could be implemented at the squadron or air-group level.

PROCEDURE AND APPARATUS

A recording of wide-band thermal noise (-3 dB/octave slope) was prepared for use on a cartridge-type tape player that normally provides the stimulus materials for the Naval Aviators' Speech Discrimination Test (NASDT) (3). The output of the tape player was connected to an 8-inch loudspeaker (Altec 403A) located inside a single-man audiometric chamber. The tape playback level was adjusted to produce a sound pressure level (SPL) of 95 dB at the ears of an individual subject. The earphone cord of the subject's helmet was connected to the earphone jack of a Tracor ARJ-4 automatic recording audiometer. Since helmet earphones are normally connected in series to provide diotic (identical) signals to both ears, only a single circuit connection was required from the audiometer. The tracing produced by the audiometer, therefore, was made only on the left-ear portion of the audiogram card. No calibration or matching of earphones was felt necessary since, for this test, only relative differences were recorded.

Subjects in the study were student flight surgeons who were in the didactic phase of instruction at the Naval Aerospace Medical Institute. Each man had been issued an APH-6C flight helmet with all modifications, including the Sonex Earcup System and the dual visor. Each man was briefed on the purpose of the test and was re-acquainted with the Békésy audiometric technique; i.e., responding to the presence of a tone by pressing a button, and releasing the button when the tone disappears. He then donned his helmet and his earphones were connected to the audiometer. A tracing of the subject's hearing threshold in quiet was thus obtained, using the earphones in the helmet. Next, the noise was turned on and a tracing of the subject's masked threshold was obtained on the same audiogram card. A typical set of tracings is shown in Figure 1.

The upper tracing on the audiogram card represents the unmasked hearing threshold. The lower tracing is of the masked hearing threshold levels obtained in the 95-dB noise field. The numerical value at each frequency is determined by drawing a horizontal line in the middle of the tracing for each frequuency and reading the corresponding value along the decibel scale. Based upon preliminary tests, 70 dB was adopted as a criterion level for masked thresholds at 500 and 1000 Hz.

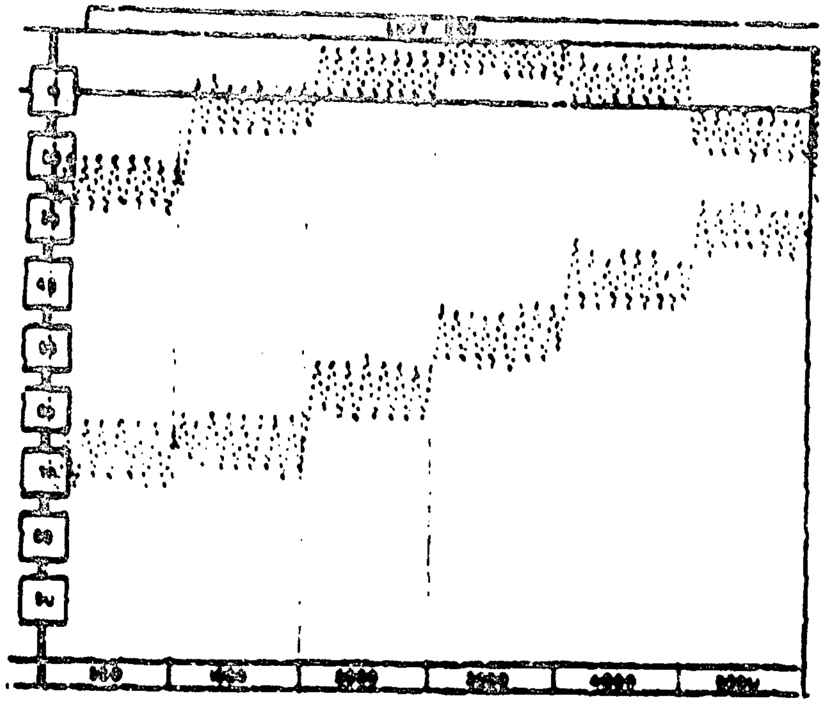

Figure 1

Sample tracings obtained on Helmet Performance Test. Upper tracing - unmasked hearing threshold; lower tracing - masked hearing threshold.

RESULTS AND DISCUSSION

A total of 42 student flight surgeons participated in the study. The results obtained on the helmet performance test are summarized in Table I.

The trend toward lower masked thresholds at higher frequencies is due to greater noise exclusion provided by the earcups. Greater importance, however, is placed on the values obtained at 500, 1000, and 2000 Hz, the frequencies which are important for the reception of speech; these frequencies are more easily masked by noise, and it is more difficult to achieve attenuation at these frequencies. Consequently, the degree of fit of the earcups may be noted more readily by observing the masked threshold levels at the speech frequencies.

Table I

Means and Standard Deviations in Decibels of Masked Threshold Values Obtained on Helmet Performance Test for Subjects Wearing the APH-6C Flight Helmet

	Frequency - Hz					
	500	1000	2000	3000	4000	6000
Mean	64.1	62.2	52.9	42.6	34.8	26.4
S.D.	4.6	5.0	4.8	5.2	5.4	6.2
N	42	42	42	40	38	34

Data for individuals with high-frequency hearing loss were excluded from Table I in order to obtain numbers that would represent normally expected values. For such individuals, masked and unmasked threshold tracings tend to overlap at the higher frequencies. This effect is illustrated in Figure 2.

In this illustration the upper tracing at 500, 1000, and 2000 Hz is the unmasked threshold and the lower tracing is of the masked threshold. For this individual the tracings overlap at 3000, 4000, and 6000 Hz. A bilateral high-frequency hearing loss in conjunction with the ambient noise levels and earcup noise exclusion properties at these frequencies produces this overlap. It is essential, therefore, that an unmasked hearing threshold be obtained prior to the masked hearing threshold; otherwise, for some individuals the obtained values would tend to indicate that the helmets were not performing well at higher frequencies.

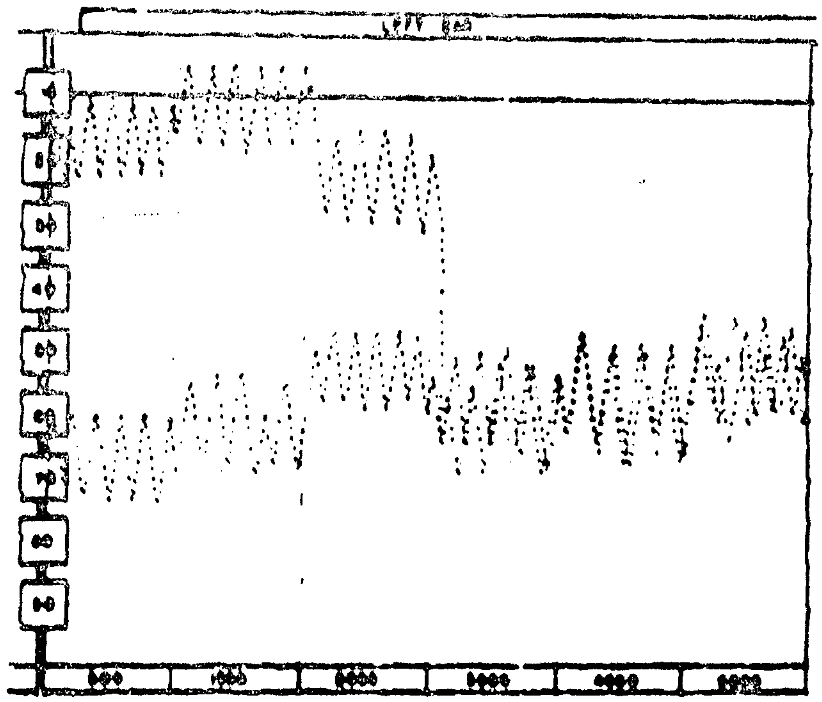

Figure 2

Sample tracings obtained on Helmet Performance Test for individual with high-frequency hearing loss.

Of the 42 student flight surgeons who participated in the study, 16 failed to meet the 70-dB criterion level. A visual inspection of the helmet fit on these individuals revealed air gaps between the seal of the earcup and the head, ranging from one-eighth inch to over one-half inch. Those individuals who appeared to have a small air gap were advised to install either one or two thin foam spacers between the earcups and the helmet shell. Five of the 16 subjects, however, were advised to exchange their large-size helmets for medium-size helmets. At a later test session, after the subjects had refitted their helmets, a second test was administered.

The values obtained during two test sessions for this group of 16 men are shown in Table II. The mean differences between the two tests represent the improvement attributable to a better fit between the earcups and the head.

From an examination of these data it appears that a slight air gap around the ear can cause a dramatic change in the noise level underneath the earcup, requiring a greater signal level to the earphones in order to achieve the same signal-to-noise ratio at the ear.

Table II

Mean Masked Threshold Levels Obtained from 16 Subjects Wearing the APH-6C Flight Helmet During Two Test Sessions

	Frequency - Hz					
	500	1000	2000	3000	4000	6000
First Test	77	73	63	55	50	39
Second Test*	64	61	52	40	32	24
Difference	13	12	11	15	18	15

*Second test was given after subjects had altered or exchanged their helmets.

In addition to obtaining masked and unmasked threshold data for the APH-6C flight helmet, masked threshold data were obtained for varying numbers of subjects for each of five other flight helmets currently in use by the Navy. These data were obtained in order to provide guidelines as to what masked threshold levels might be expected for the various helmets. The obtained values for each of the helmets, including the APH-6C, are shown in Table III.

While it is not surprising, it is interesting and encouraging to note that the two best Navy helmets, the APH-6C and the SPH-3B, show masked threshold levels that are lower than levels obtained for the other four helmets. The APH-6C (Sonex equipped) and the SPH-3B (with earcups almost identical to those of the APH-6C) are current state-of-the-art helmets, and represent a significant improvement over their predecessors. The lower masked thresholds obtained for the two helmets indicate that some form of masked threshold test could be helpful in evaluating the overall acoustical performance of flight helmets.

REFERENCES

1. Standard method for the measurement of the real-ear attenuation of ear protectors at threshold. Z24.22. New York: American National Standards Institute, 1957.

2. Sonar detection of submarines by helicopter. Report by Working Group 54 of Committee on Hearing, Bioacoustics, and Biomechanics (CHABA). Arlington, Virginia, 1970.

3. Greene, J. W., The naval aviator's speech discrimination test: Instrumentation and technique. NAMI-1027. Pensacola, Fla.: Naval Aerospace Medical Institute, 1967.

Table III

Mean Masked Threshold Values in Decibels for Six Navy Helmets Obtained with Helmet Performance Test

	Subjects	Frequency - Hz					
	N	500	1000	2000	3000	4000	6000
APH-5	3	78	73	66	60	53	41
APH-6	7	93	83	74	65	53	41
APH-6A (Mod)*	5	75	74	64	54	42	32
APH-6C (Bonex)	42	64	62	53	43	35	26
APH-3A	5	79	79	68	57	47	35
APH-3B	4	67	69	58	48	41	26

*Modification consists of application of sealant around the periphery of large foam earmuff.

CONCLUSIONS

A noise source and an automatic recording audiometer provide an efficient means of determining the optimal fit of flight helmets. The noise source allows one to detect any acoustical leakage around his ears so that a better fit can be effected. Masked hearing threshold levels obtained through the helmet's earphones can be compared with masked threshold values obtained for that particular helmet. Such a procedure would appear feasible for effective implementation at the squadron or airgroup level.

REFERENCES

1. Standard method for the measurement of the real-ear attenuation of ear protectors at threshold. Z24.22. New York: American National Standards Institute, 1957.

2. Sonar detection of submarines by helicopter. Report by Working Group 54 of Committee on Hearing, Bioacoustics, and Biomechanics (CHABA). Arlington, Virginia, 1970.

3. Greene, J. W., The naval aviator's speech discrimination test: Instrumentation and technique. NAMI-1027. Pensacola, Fla.: Naval Aerospace Medical Institute, 1967.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Flight helmets						
Noise attenuation						
Masked threshold						
Helmet performance						